

# Epidemiological Studies of Plague in India

## 2. The Changing Pattern of Rodents and Fleas in Calcutta and Other Cities

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*Data from early in the twentieth century up to the present day indicate that Rattus rattus among rodents and Xenopsylla cheopis among fleas are the two most important elements in urban human plague infection in India, R. norvegicus playing a more minor role. The relative numbers of both these species have decreased in recent years in Bombay and Calcutta, while those of Bandicota bengalensis, which is less heavily parasitized by X. cheopis, have risen. This reduction in the numbers of the epidemiologically more important rodents and their fleas has been accompanied by a reduction in the number of human plague cases.*

The first known human plague epidemic in Calcutta started in the year 1895 and the disease did not completely disappear from the city until 1925. After a lapse of 23 years it reappeared in 1948 and remained for four years. The peak years were 1900-07 in the first epidemic and 1949 in the last outbreak. The city of Bombay became infected in 1896, and the disease remained rampant there until 1923, when it gradually waned to stop completely in 1935. It reappeared in Bombay in 1948 (the same year as in Calcutta) and also recurred in 1949 and 1952, but drastic efforts were made successfully to prevent its spread. During these epidemics a number of interesting observations were made regarding the distribution of rats and the general and specific flea indices. These are summarized in the various tables accompanying this article.

### RODENT DATA

#### *Rat species and distribution*

The data in Table 1 show that in Madras, *Rattus rattus* was the predominant species until 1930, at which time, indeed, it was practically the only species present. (No more recent data are available.) In Calcutta this domestic species made up only 14.0% of the total in 1906 and remained at almost the same level until 1950; since the last epidemic, however, it has suffered a reduction of some 50%. *R. norvegicus*, the common brown rat of Europe, is

not heavily represented in Calcutta and has fluctuated between 9.0% and 26.0% during the last few years. The relative proportions of rats in Bombay have also undergone important changes, *R. rattus* falling from 66.2% in 1910 to 23%-24% and *R. norvegicus* from 28.7% to 15.9% in 1956. The biggest change in Bombay has been in the proportions of *Bandicota bengalensis* (*Gunomys kok*), which constituted only 1.0% of the total in 1910 and has now risen to 49%-50%. This rodent being fairly susceptible, the city is considered by some workers to be vulnerable to plague infection, and human cases were actually reported in the city in 1948, 1949 and 1952. Fortunately *R. rattus* and *R. norvegicus* are still very resistant to plague.

#### *Rodent densities in Calcutta, 1948-50*

A total of 38 241 cage traps were laid during the years 1948-50 in different wards of the city and 15 984 rats were caught (few rats escaped). The average density was 41.7, varying from 5.5 in ward 15 to 81.8 in ward 32 (Table 2). These densities were not, however, related to the incidence of human plague, which depended upon the prevalence of types of rodents and fleas. The density of *R. rattus* was below 1.0 in at least eight wards and above 3.0 in nine wards, the maximum being 13.4 in ward 4 and 8.5 in ward 8, both plague-infected. In the remaining 15 wards it ranged between 1.0 and 3.0.

The rodent densities by months (1949-50) are given in Table 3, from which it will be seen that the highest density (133.7) occurred in April, the peak month for human plague cases. There was a fall,

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TABLE 1  
PERCENTAGE DISTRIBUTION OF DIFFERENT SPECIES OF RODENTS IN CALCUTTA, BOMBAY AND MADRAS

City	Investigator and year	<i>Rattus rattus</i>	<i>Rattus norvegicus</i>	<i>Bandicota bengalensis</i>	<i>Bandicota indica</i>	Other rodents
Calcutta	Hossack, 1906	14.0	26.0	60.0	—	—
	Rao, 1936	13.5	22.0	27.3	—	37.2
	Seal & Bhattacharji, 1948-50 <sup>a</sup>	13.3	9.0	75.8	1.7	—
	Chaudhuri, <sup>a</sup> 1951	6.1	17.3	75.8	0.75	—
	„ 1952	6.5	24.3	68.1	1.1	—
	„ 1953	6.1	26.1	66.6	1.2	—
	„ 1954	5.6	23.8	69.8	0.8	—
	„ 1955	5.2	17.2	73.1	0.5	—
„ 1956	7.3	9.0	79.9	0.3	—	
Bombay	Indian Plague Commission, 1910	66.2	28.7	1.0	—	4.1
	Webster & Chitre, 1929-30	79.1	11.0	9.9	—	—
	Medical Officer of Health, Bombay, 1946 <sup>a</sup>	23.7	18.3	47.4	—	10.0
	Haffkine Institute, 1952	22.6	17.7	38.1	—	21.6
	„ 1954	24.7	17.8	38.1	—	19.4
	„ 1956	22.9	15.9	49.2	—	12.0
Madras	Indian Plague Commission, 1910	49.4	—	—	—	50.6
	King & Pandit, 1931	98.8	—	—	—	1.2

<sup>a</sup> Unpublished data.

TABLE 2  
RODENT DENSITIES IN DIFFERENT WARDS OF CALCUTTA CITY, 1940-50

Wards	Rodent density	Wards	Rodent density
1	31.8	18	10.1
2	59.3	19	20.7
3	58.3	20	47.0
4	33.0	21	35.3
5	56.0	22	27.7
6	57.5	23	54.2
7	58.1	24	53.3
8	40.0	25	43.2
9	28.1	26	16.6
10	30.0	27	62.2
11	19.1	28	34.6
13	52.5	29	62.1
14	36.5	30	33.7
15	5.5	31	12.0
16	24.7	32	81.8
17	—	Other areas	5.5
		Average	42.2

TABLE 3  
RODENT DENSITIES IN CALCUTTA BY MONTHS, 1948-49 AND 1949-50

Months	No. of cage traps	Rats caught	Rodent density
April	1 616	2 226	137.7
May	4 416	1 797	40.6
June	3 072	1 546	50.3
July	2 862	755	26.3
August	3 295	1 042	31.6
September	4 004	787	19.6
October	3 761	512	13.6
November	3 705	1 173	31.6
December	3 665	1 942	53.0
January	2 497	1 456	58.6
February	2 503	1 282	51.2
March	2 845	1 430	50.2
Total	38 241	15 948	41.7

TABLE 4  
RESULTS OF RESISTANCE TESTS OF RATS CAUGHT IN FOUR WARDS OF CALCUTTA CITY, 1953-54

Species	Ward 8		Ward 10		Ward 22		Ward 25		Total	
	No. surviving/ No. tested	% mortality								
<i>R. rattus</i>	18/30	60.0	22/22	100.0	14/16	87.5	16/18	88.9	70/86	81.0
<i>R. norvegicus</i>	26/28	92.8	18/18	100.0	13/14	92.7	15/16	93.9	72/76	94.7
<i>B. bengalensis</i>	54/56	98.2	55/55	100.0	40/50	98.0	49/51	98.0	207/212	97.6
Total	98/144	86.0	95/95	100.0	76/80	95.0	80/85	94.1	349/374	93.2

fluctuating slightly, from May to October (13.6), following which there was an almost consistent rise, as may be seen from the accompanying figure.

#### Resistance of local rat populations, 1953-54

A total of 374 rats (114 from ward 8, 95 from ward 10, 85 from ward 25 and 80 from ward 22) were tested in 1953-54 for resistance to plague with an infective dose of 5000 virulent organisms (Table 4). In certain subsequent experiments 2500, 500 and even 100 organisms were used, without affecting the results except by delaying death for a few days.

While in ward 8, the original focus of plague infection, 16 out of 114 rats survived (14.0%), both *R. norvegicus* and *B. bengalensis* were still susceptible; only *R. rattus* showed a fair degree of resistance (40% survival). In ward 10 (plague-free) all rats died. In wards 22 and 25 *R. rattus* was only partially resistant (19.0% survival), and the other rats were highly susceptible. In Bombay, on the other hand, *R. rattus* and *R. norvegicus* were found highly resistant, only *B. bengalensis* being susceptible (Table 5). Madras rats are fully susceptible, accord-

RODENT DENSITY IN CALCUTTA, 1948-50

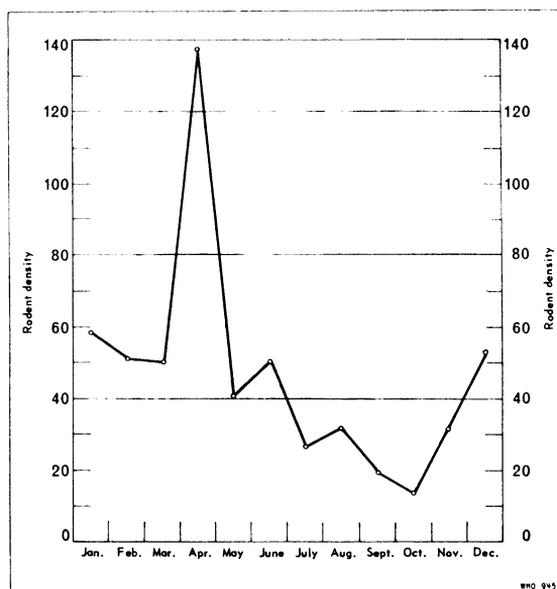


TABLE 5  
PERCENTAGE MORTALITY AMONG BOMBAY RATS IN RESISTANCE TESTS  
CONDUCTED BY HAFKINE INSTITUTE, COMPARED WITH CALCUTTA DATA

Species	Bombay					Calcutta, 1953-54
	1952	1953	1954	1955	1956	
<i>R. rattus</i>	12.6	13.7	12.1	10.0	7.5	81.0
<i>R. norvegicus</i>	—	5.8	3.3	2.6	2.2	94.7
<i>B. bengalensis</i>	77.6	82.5	76.7	70.0	75.2	97.6

TABLE 6  
PERCENTAGE DISTRIBUTION OF DIFFERENT FLEA SPECIES IN CALCUTTA, BOMBAY AND MADRAS

City	Investigator and year	<i>X. cheopis</i>	<i>X. astia</i>	<i>X. brasiliensis</i>	<i>Ctenocephalides</i>	<i>Pulex irritans</i>
Calcutta	Strickland & Roy, 1925-26	40.0	60.0	—	—	—
	Rao, 1936; 1941	40.4	59.6	—	—	—
	Seal & Bhattacharji, 1948-50 <sup>a</sup>	34.4	65.6	—	4 fleas	—
Bombay	Cragg, 1920;	49.5	49.8	0.7	—	—
	„ 1923	53.1	45.8	1.0	—	—
	Webster, 1928 <sup>b</sup>	77.5	19.2	3.1	—	—
	Webster & Chitre, 1930	69.6	27.9	3.3	—	—
	Deoras & Tonpi, 1956	76.3	23.7	0.0	—	—
Madras	King & Pandit, 1931	5.6	94.3	1 flea	1 flea	1 flea

<sup>a</sup> Unpublished data.<sup>b</sup> Quoted by Deoras & Tonpi.

TABLE 7  
GENERAL AND SPECIFIC FLEA INDICES IN CALCUTTA, BOMBAY AND MADRAS

City	Investigator and year	General flea index	<i>X. cheopis</i> index	<i>X. astia</i> index	<i>X. brasiliensis</i> index
Calcutta	Strickland & Roy, 1925-26	0.6	0.16	0.4	—
	Rao, 1936	5.7	2.3	3.4	—
	Seal & Bhattacharji, 1948-50 <sup>a</sup>	1.1	0.4	0.7	—
	Chaudhuri, <sup>a</sup> 1951	0.56	0.12	0.44	—
	„ <i>minimum</i>	0.27 Oct.	0.03 Nov.	0.23 June	
	„ <i>maximum</i>	1.01 April	0.31 April	0.71 March	
	„ 1954	0.84	0.19	0.65	
	„ <i>minimum</i>	0.51 June	0.06 Nov.	0.46 Nov.	
	„ <i>maximum</i>	1.63 March	0.58 March	1.25 March	
	„ 1957	0.40	0.05	0.35	
„ <i>minimum</i>	0.28 Jan.	0.01 Jan.	0.21 Jan.		
„ <i>maximum</i>	1.29 Oct.	0.17 Oct.	1.12 Oct.		
Bombay	Webster & Chitre, 1930	6.3	3.1	3.1	0.1
	Deoras & Tonpi, 1956	1.58	1.2	0.37	0.0
Madras	King & Pandit, 1931	2.6	0.1	2.5	1 flea

<sup>a</sup> Unpublished data.

TABLE 8  
WEEKLY *X. CHEOPIS* AND *X. ASTIA* INDICES IN  
PLAGUE-INFECTED WARDS IN CALCUTTA, 1949

Week ending	<i>X. cheopis</i>	<i>X. astia</i>	Total
January 15	1.05	2.08	3.13
" 22	0.33	1.4	1.37
" 29	0.77	2.3	3.07
February 5	0.39	2.5	2.89
" 12	0.22	1.6	1.82
" 19	0.35	1.9	2.25
" 26	1.6	1.1	2.70
March 5	0.98	0.94	1.92
" 12	0.32	0.56	0.88
" 19	0.62	0.25	0.98
" 26	0.83	0.55	1.38
April 2	0.21	0.59	0.80
" 9	0.24	0.58	0.82
" 16	0.23	0.32	0.55
" 23	0.58	0.54	1.12
" 30	0.24	0.16	0.40
May 7	0.69	0.32	1.01
" 14	1.7	0.72	2.42
" 21	1.4	0.32	1.72
" 28	1.4	0.42	1.82
June 4	0.27	0.59	0.86

ing to the results of tests made by the Haffkine Institute.

#### FLEA DATA

##### *Flea species and distribution*

Table 6 shows that in Calcutta the predominant flea is *Xenopsylla astia* (65.6%) and in Bombay *X. cheopis* (76.3%). In Madras *X. astia* has been practically the only flea of importance (94.3%), but recent figures are not available. The percentage of *X. astia* in Calcutta seems to have been increasing since 1925 at the expense of *X. cheopis*. Bombay in 1920 had almost equal proportions of these two fleas, the trend towards predominance of *X. cheopis* becoming significant in 1928 and being maintained thereafter; *X. brasiliensis*, which was found there in a low percentage, has now practically disappeared. It may be mentioned here that Madras City has always been almost entirely free from plague.

##### *Flea indices* (Table 7)

In Calcutta the general flea indices and the *X. cheopis* indices have been low since 1948, and more particularly during the last few years, according to P. Chaudhuri (personal communication, 1958), who has been carrying out flea and rat control measures in the city for the past six or seven years.

An interesting point is that plague was raging in Calcutta during 1948-50, even when the average *X. cheopis* index was as low as 0.4. However, during the 1949 epidemic both this index (Table 8) and the *R. rattus* index increased in the focal plague areas during the rise of the epidemic, and a noticeable difference was found between the plague-affected and the plague-free wards. Another point of interest is that both the general and the *X. cheopis* indices were very low in 1925-26, when plague ceased in Calcutta after the first epidemic; these indices have now been still further reduced, and this may explain the current absence of human plague in the city in spite of the fact that occasional infection of rats is still detected. It has also been observed that both the general and the *X. cheopis* indices are usually highest in March-April and lowest in October-November (see Table 7), although in 1957, for instance, the situation was reversed as regards the general flea index through the influence of *X. astia*.

For Bombay recent data also show much reduction in the flea indices—1.58 in 1953 as against 6.3 in 1930.

There are no recent figures for Madras, but the *X. cheopis* index was very low there in 1931 and this may be one of the reasons for the absence of plague in that city.

From the data in Table 9 it may be seen that in plague-affected cities like Bombay and Calcutta *X. cheopis* parasitizes *R. rattus* and *R. norvegicus* more than *B. bengalensis*. *B. bengalensis* carry more *X. astia* than *X. cheopis* in Calcutta but not in Bombay. The danger of plague is clearly much greater from the two *Rattus* species than from the bandicoot. This is corroborated by our findings in the last outbreak at Calcutta. Out of a total of 50 rats found bacteriologically plague-infected the percentage distribution was: *R. rattus*, 46%; *R. norvegicus*, 34%; *B. bengalensis*, 18%; others, 18%. The first two together form 80% of the total positive.

##### *Examination of fleas for plague infection*

In experiments conducted in wards 8 and 10 of Calcutta in 1953-54 (Table 10) fleas from each rat cage were pooled and crushed for mouse inoculation and culture. Except for one pool from ward 8 in March 1954, all samples proved negative. There were no human cases in 1953 or 1954 but rats were found positive on several occasions (P. Chaudhuri—personal communication, 1958).

TABLE 9  
FLEA INDICES ACCORDING TO RAT SPECIES IN CALCUTTA, BOMBAY AND MADRAS

City	Investigator and year	<i>R. rattus</i>		<i>R. norvegicus</i>		<i>B. bengalensis</i>	
		<i>X. cheopis</i> index	<i>X. astia</i> index	<i>X. cheopis</i> index	<i>X. astia</i> index	<i>X. cheopis</i> index	<i>X. astia</i> index
Calcutta	Strickland & Roy, 1925-26	low	low	0.85	2.51	1.17	2.35
	Rao, 1936	3.0	1.3	3.3	6.1	1.4	3.7
	Seal & Bhattacharji, 1948-50; 1952-53 <sup>a</sup>	0.8	0.6	0.9	1.0	0.2	0.7
Bombay	Webster & Chitre, 1930	3.7	0.5	4.4	2.5	9.2	2.7
	Deoras & Tonpi, 1956	1.44	0.17	—	—	0.9	0.63
Madras	King & Pandit, 1931	0.2	3.7	—	—	—	—

<sup>a</sup> Unpublished data.

TABLE 10  
NUMBERS OF FLEAS EXAMINED FROM WARDS 8 AND 10 IN CALCUTTA CITY, 1953-54

Ward	<i>X. cheopis</i>			<i>X. astia</i>		
	Male	Female	Total	Male	Female	Total
8	229	418	647	240	484	724
10	258	423	681	630	1 257	1 887
Total	487	841	1 328	870	1 741	2 611

TABLE 11  
RELATIONSHIP BETWEEN FLEA INDICES, PLAGUE CASES AND RAT INFECTION  
IN CALCUTTA BY TRIMESTRIAL PERIOD OF 1949

Period	<i>X. cheopis</i> index	<i>X. astia</i> index	Total flea index	Percentage of infected rats	Percentage of plague cases
January-March	1.0	0.8	1.8	38.0	12.5
April-June	0.6	0.6	1.2	54.0	81.0
July-September	0.6	1.2	1.8	2.0	5.5
October- December	0.1	0.6	0.7	6.0	1.0

The relative proportion of the two species of fleas differed in the two wards, being 112 *X. astia* per 100 *X. cheopis* in ward 8 and 277 *X. astia* per 100 *X. cheopis* in ward 10. The average daily number collected fell to a comparatively low figure between July and November and also in February. It was high in December and again in March-June, with the highest peak of collection in March. Thus laboratory observations support those made in the field.

#### *Relationship of flea indices to plague cases*

The *X. cheopis* index in 1949 was found to be highest in Calcutta during January-March and lowest in October-December, while the percentages of rats positive and of human cases were highest in April-June and lowest in October-December (Table 11). It appears that the *X. cheopis* index remains high in March-April, when the rat epizootic starts. The number of human cases builds up about two weeks later, which explains the higher percentage being found in the April-June period. Closer analysis, however, shows that there is a distinct relationship between the *X. cheopis* index and the epizootics as well as the human epidemic.

#### CONCLUDING REMARKS

Although *B. bengalensis* have been found infected with plague and although chronic plague has also been found frequently among them in Calcutta, it appears from the above data that among the rodents *R. rattus* and among the fleas *X. cheopis* are the two important elements (reservoir plus vector) in urban human plague infection in India. If either of them can be kept down, the risk of human plague can be reduced to a minimum. *R. rattus* abounds in bustees (slum areas) and houses with tiled or thatched roofs and in godowns and mills.

The city which can completely do away with houses of these kinds and which can properly control conditions in godowns and mills can perhaps eliminate *R. rattus*. Well-built brick houses with rat-proofing devices offer no shelter to *R. rattus*. Wherever such buildings are found in large numbers *R. rattus* is scanty or absent, and human plague is not seen. The *R. rattus* density, however, is fairly high in ward 8 in Calcutta, and it is there that plague has always been found to start.

Another way to control urban plague would be to keep the *X. cheopis* index at a negligible level or to attempt to eradicate the species altogether.

#### RÉSUMÉ

Au cours des épidémies de peste et des années de silence qui se sont succédé à Calcutta et à Bombay, de 1895 au temps présent, des observations ont été faites sur la population des rongeurs et des puces. L'auteur les résume dans cet article.

La répartition des rongeurs et des puces a beaucoup changé, ces dernières années, dans les villes atteintes de peste — Calcutta et Bombay — et dans la ville indemne de Madras. A Calcutta, la proportion de *R. rattus* était déjà faible. Elle a récemment diminué encore de moitié. La population de *R. norvegicus* a montré une tendance nette à la réduction, cédant le pas à *Bandicota bengalensis* (qui représente maintenant 80% des rongeurs). A Bombay aussi, *R. rattus* a passé de 79% à 22,9%, tandis que *B. bengalensis* augmentait de 1% à 40%. A Madras, *R. rattus* garde la priorité avec 98%. Tandis que *R. rattus* et *R. norvegicus* sont restés fortement résistants à la peste, à Bombay, ils ne le

sont que partiellement à Calcutta. *B. bengalensis* est pleinement sensible.

La densité de la population des rats est élevée à Calcutta, mais celle de *R. rattus* est basse, sauf dans deux quartiers fortement touchés par la peste. Dans cette ville, la proportion des puces *X. cheopis* est beaucoup plus faible que celle des *astia*, mais c'est l'inverse à Bombay. A Madras, *astia* représente 94%. La saison où l'indice est élevé est en général mars-avril, le minimum se situant en octobre-novembre.

En conclusion, l'auteur estime que les deux éléments importants de l'infection pesteuse en Inde sont *R. rattus* et *X. cheopis*, bien que la peste chronique ait été trouvée fréquemment parmi les bandicots. La réduction de ces deux espèces abaissera le risque de peste à un minimum. La construction des bâtiments à l'épreuve des rats (rat proof) a éliminé pratiquement *R. rattus* et la peste des quartiers où elle est adoptée.

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